Canadian Institute of
Guided Ground Transport
Queen's University
at Kingston, Ontario

G.W. English

CIGGT Report No. 88-9
Transport Canada Report No. TP 9540E

prepared for

Transportation Development Centre
Policy and Coordination Group
Transport Canada

October 1988

CA1
DTC 800
88
D25
c.2

mm
CA1
DTC 300
88
D25
C.2

CIGGT Project No. PRO-762

CIGGT Report No. 88-9
Transport Canada Report No. TP-9540E

Library and Information Centre / Centre de Documentation (GSL)
RECEIVED - REÇU LE
APR 21 1989
Transport Canada / Transports Canada

Working Paper

DEVELOPMENT OF AN OPERATIONS SIMULATOR FOR EVALUATION OF ATCS MODULES

G.W. English

prepared for

Transportation Development Centre
Policy and Coordination Group
Transport Canada

Canadian Institute of Guided Ground Transport
Queen's University at Kingston
K7L 3N6

October 1988

412862

ACKNOWLEDGEMENT

The author would like to thank Dr. H. Mouftah and Mr. Simon Pan for their comments and assistance in undertaking this review. The support of the Transportation Development Centre and Mr. Wayne Rowan in particular is also appreciated.

ISBN 0 88911 065 4

Un sommaire en français de ce rapport est inclus avant la Table des matrières.

This report resulted from research conducted through the Canadian Institute of Guided Ground Transport. The report represents the views of the author and does not necessarily have the endorsement of the University, the Transportation Development Centre of Transport Canada, or the other participating organizations.

Transport Canada / Transports Canada

PUBLICATION DATA FORM

1. Transport Canada Publication No.	2. Project No.	3. Recipient's Catalogue No.
TP 9540E	6992, Task #2	

4. Title and Subtitle	5. Publication Date
DEVELOPMENT OF AN OPERATIONS SIMULATOR FOR EVALUATION OF ATCS MODULES	October 1988
	6. Performing Organization Document No. 88-9
7. Author(s) G.W. English	8. Transport Canada File No. D1465-6-8,9
9. Performing Organization Name and Address Canadian Institute of Guided Ground Transport (CIGGT) Queen's University at Kingston, Ontario K7L 3N6	10. DSS File No. 14SD.T8200-7-7537 11. DSS or Transport Canada Contract No. T8200-7-7537/01-SD, Task #2
12. Sponsoring Agency Name and Address Transportation Development Centre (TDC) 200 René Lévesque Blvd West West Tower, Suite 601 Montréal, Québec H2Z 1X4	13. Type of Publication and Period Covered Working Paper 14. Project Officer W.G. Rowan

15. Supplementary Notes (Funding programs, titles of related publications, etc.)

16. Abstract

One of the major impediments to suppliers of railway signalling equipment is the limited ability and high cost of in-service testing. The operational performance of Advanced Train Control Systems (ATCS) can be evaluated via computer simulation of a rail line's operations. This working paper presents the findings of a study of the market potential for such a simulator. The development phases initially proposed were: an operations simulator, a locomotive component simulator and a communications simulator. Presentations to industry and follow-up questionnaires were used to assess the need for the proposed simulators. Most of the interest demonstrated by industry was in the development of a full test facility rather than an operations simulator. The first step in this direction which was of immediate interest is a simulated interface to the locomotive on-board computer. The necessary specifications for a limited interface to a dispatch centre or to an on-board computer are either in place or will be shortly.

17. Key Words	18. Distribution Statement
Advanced train control, Simulation, Rail operations	Available on request from Canadian Institute of Guided Ground Transport or Transportation Development Centre

19. Security Classification (of this publication)	20. Security Classification (of this page)	21. Declassification (date)	22. No. of Pages	23. Price
unclassified	unclassified		vi,14+append.	

Transports Canada / Transport Canada

FORMULE DE DONNÉES POUR PUBLICATION

1. N° de la publication de Transports Canada	2. N° de l'étude	3. N° de catalogue du destinataire
TP 9540E	6992, Travail #2	

4. Titre et sous-titre

DEVELOPMENT OF AN OPERATIONS SIMULATOR FOR EVALUATION OF ATCS MODULES

5. Date de la publication: Octobre 1988

6. N° du document de l'organisme exécutant: 88-9

7. Auteur(s): G.W. English

8. N° de dossier — Transports Canada: D1465-6-8,9

9. Nom et adresse de l'organisme exécutant:

Canadian Institute of Guided Ground Transport (CIGGT)
Queen's University at Kingston, Ontario
K7L 3N6

10. N° de dossier — ASC: 14SD.T8200-7-7537

11. N° de contrat — ASC ou Transports Canada: T8200-7-7537/01-SD, #2

12. Nom et adresse de l'organisme parrain:

Centre de développement des transports (CDT)
200 ouest, boul. René Lévesque
Tour ouest, suite 601
Montréal (Québec) H2Z 1X4

13. Genre de publication et période visée: Brouillon

14. Agent de projet: W.G. Rowan

15. Remarques additionnelles (Programmes de financement, titres de publications connexes, etc.)

16. Résumé

Le principal obstacle sur lequel bute la mise au point d'équipements de signalisation ferroviaire est celui de leur exploitation en service expérimental, difficulté due à la rareté des occasions et aussi au coût à consentir. Or, l'avantage des systèmes avancés de commande des trains à ce chapitre réside dans le fait que leurs performances peuvent être évaluées par voie de simulation assistée par ordinateur des opérations ferroviaires. Ce document de travail présente le résultat d'une étude de marché portant sur un tel simulateur. Les répondants avaient à choisir entre : un simulateur d'opérations ferroviaires, un appareil simulant l'interface avec l'ordinateur à bord de la locomotive et un simulateur de communications. Des journées de présentation avaient été organisées à l'intention des milieux concernés, et des questionnaires envoyés aux participants. Le secteur privé s'est prononcé, pour une large part en faveur d'une installation d'essai de systèmes complets de préférence au simulateur d'opérations ferroviaires; la première étape devant être la mise au point d'un appareil simulant l'interface avec l'ordinatuer à bord de la locomotive. Les spécifications relatives à une interface partielle avec un poste de régulation ou un ordinateur embarqué ont été, ou seront bientôt, élaborées.

17. Mots clés	18. Diffusion
système avancé de commande des trains, simulation, opérations ferroviaires	S'adresser au Canadian Institute of Guided Ground Transport ou au Centre de développement des transport

19. Classification de sécurité (de cette publication)	20. Classification de sécurité (de cette page)	21. Déclassification (date)	22. Nombre de pages	23. Prix
non classifié	non classifiée		vi,14+append.	

CDT/TDC 79-005
Rev 88

Canada

SUMMARY

Recent initiatives on the part of Canadian railways in the area of advanced signalling and train control hold promise for the creation of a Canadian railway signalling industry. The trend is away from past technology, dominated by U.S. suppliers, to microprocessor- based systems which are widely accepted in Europe. There is an opportunity for Canadian industry to get solidly involved in the transitional stage.

The major development effort required is in the areas of systems engineering, software development and microprocessor applications: areas in which Canada has a demonstrated competence and in which several government initiatives have been targeted.

One of the major impediments to suppliers of railway signal equipment is the limited availability and high cost of in-service testing. The advantage of advanced train control systems (ATCS) in this regard is that much of the development is systems engineering. The operational performance of these systems can be evaluated via computer simulation of a rail line's operations. The simulation approach allows a rapid evaluation time, and permits user determination of the numbers and characteristics of the rail line as opposed to the time-consuming passive monitoring of a field installation. Three segments in particular lend themselves to simulation testing: the dispatch centre, the on-board computer, and the communications modules.

The objective of this working paper was to assess the interest in a simulation test facility. Invitations were sent to industry, railway and government representatives to attend one of two presentations (one in Montreal and one in Toronto) detailing the proposed facility. Following the presentations questionnaires were sent to the attendees, soliciting their reaction to the proposal.

Most of the interest was in a full test facility but the operations simulator and communications test facility were of prime interest to some. The simulator for the on-board locomotive equipment was of principal interest to the suppliers. Of the on-board equipment, the on-board computer is the vital component which depends on software development. A simulated interface to this processor was seen as a desirable first step.

The requirements of the initial interface are confined to those elements considered to be part of the vital operation of the train. Health monitoring interfaces would not be included at this stage. The control settings of the locomotive will be provided by an expert system's based driver module which will be sensitive to the control objectives of the particular train being simulated. The train response to the control settings will include probability of wheel slip and initial errors in wheel diameters. The interface with the dispatch centre requires a rudimentary form of dispatch logic. This module will have a capability of giving authorities for train movement in relation to predefined scenario of stop locations, speed limits, and temporary slow orders.

SOMMAIRE

Les programmes lancés par les sociétés canadiennes de chemin de fer dans le domaine des systèmes avancés de signalisation farroviaire et de commande des trains portent en eux le germe d'une nouvelle industrie canadienne vouée à la signalisation ferroviaire. Marquant le détachement qui se fait sentir actuellement vis-à-vis de la technologie dominée jusqu'ici par les fournisseurs américains, ils soulignent la tendance vers les systèmes pilotés au moyen de microprocesseurs, déjà très répandus en Europe. Voilà donc l'occasion, pour le Canada, de tirer profit de cette période transitoire afin de s'implanter soidement dans le secteur en question.

Il s'avère par ailleurs que l'effort de recherche et de développement à consentir s'inscrit principalement dans les domaines de la systémique, de l'informatique et de la microélectronique appliquées, secteurs pour lesquels le Canada a déjà prouvé sa compétenie et qui, de surcroît, sont le point de mire déclaré de plusieurs Pouvoirs publics.

Le principal obstacle sur lequel bute la mise au point d'équipements de signalisation ferroviaire est celui de leur exploitation en service expérimental, difficulté due à la rareté des occasions et aussi au coût à consentir. Or, les avantages des systèmes avancés de commande des trains (SACT) à ce chapitre résident justement dans le fait que leur mise au point fait largement appel à la systémique et que leurs performances peuvent être évaluées par voie de simulation assistée par ordinateur des opérations ferroviaires. La simulation non seulement permet-elle d'écourter le temps consacré aux évaluations techniques, mais aussi d'appliquer au modèle les valeurs d'entrée et les paramètres d'une liaison ferroviaire, au choix de l'utilisateur, aui n'aura plus ainsi à attendre d'avoir rassemblé assez de données pour les soumettre à la l'analyse. Trois fonctions en particulier se prêtent à la simulation : le centre de régulation, l'ordinateur embarqué et les modules de communication.

Le présent document de travail vise à mettre en évidence l'intérêt éventuel pour un simulateur d'opérations ferroviaires. À cet effet, deux journées de présentation ont été organisées, l'une à Montréal et l'autre à Toronto, à l'intention des milieux concernés : secteurs public et privé et sociétés ferroviaires. Des questionnaires ont été par la suit envoyés aux participants, leur demandant de faire connaître leur réaction à la proposition.

La plupart se sont prononcés en faveur d'une installation d'essai de systèmes complets, bien que quelques-uns aient opté pour le simulateur d'opérations ferroviaires et le simulateur de communications. La préférence des fournisseurs est allée au simulateur des opérations à bord de la locomotive, lesquelles sont prises en charge par le matériel embarqué et notamment l'ordinateur incipte à fonctionner sans logiciel. Un appareil simulant l'interface avec cet ordinateur a été considéré comme une première étape souhaitable.

Pour commencer, cet appareil devrait avoir les caractéristiques lui permettant de simuler les seules fonctions vitales d'une locomotive; par conséquent, la fonction de diagnoistic ne devrait pas être envisagée à cette étape-ci. Le train dont en veut simuler la marche sera commandé par un module de conduite à base de système expert capable d'imprimer à la locomotive l'allure qui convient le mieux à la mission du train. Parmi les paramètres de marche pris en compte, figureront les caractéristiques d'adhérence roue-rail et les écarts dans le diamètre d'origine des roues. L'interface avec le centre de régulation nécessitera une architecture logique rudimentaire capable d'émettre des instructions concernant les mouvements d'un train en fonction de paramètre pré-établis : emplacement des arrêts obligatoires, limites de vitesse à respecter et ordres provisoires de marche au ralenti.

TABLE OF CONTENTS

1. INTRODUCTION 1

2. FEATURES OF THE PROPOSED SIMULATOR 2

3. MARKET ASSESSMENT 4

4. PERFORMANCE SPECIFICATIONS 8
   4.1 The Operations Simulator 8
   4.2 The On-Board Computer Interface Simulator 12

5. CONCLUSIONS 15

Appendix A: PRESENTATION TO INTERESTED INDUSTRY, RAILWAY AND GOVERNMENT REPRESENTATIVES

LIST OF TABLES

1. Simulation Test Facility for ATCS and Like Systems Questionnaire Results -- Recapitulation 1

LIST OF FIGURES

1. ATCS Data System Topology and Major Internal Connections 3
2. Questionnaire 5
3. Configuration of Operations Simulator 8
4. ATCS Data Network by OSI Layer 10
5. Interface to Locomotive On-Board Computer 12
6. Elements of Simulator 13

1. INTRODUCTION

Recent initiatives on the part of Canadian railways in the area of advanced signalling and train control hold promise for the creation of a Canadian railway signalling industry. The trend is away from past technology, dominated by US suppliers, to microprocessor-based systems which are widely accepted in Europe. There is an opportunity for Canadian industry to get solidly involved in the transitional stage.

The additional information and dispatcher support functions offered by Advanced Train Control Systems (ATCS) will lead to significant productivity improvements. Track capacity utilization enhancements are also forecast for advanced train control systems. The system can draw upon existing products for its communications hardware requirements. The major development effort would be in the areas of systems engineering, software development and microprocessor applications -- areas in which Canada has a demonstrated competence and in which several government initiatives have been targeted.

One of the major impediments to suppliers of railway signalling equipment is the limited availability and high cost of in-service testing. The advantage of ATCS in this regard is that much of the development is systems engineering and software development. The operational performance of these systems can be evaluated via computer simulation of a rail line's operations. The simulation approach allows a rapid evaluation time, and permits user determination of the numbers and characteristics of the rail line as opposed to the time-consuming passive monitoring of a field installation. There are obvious safety benefits to having an off-line simulation facility to conduct safety assurance testing rather than monitoring in-service performance.

On the basis of this perceived need, CIGGT made a proposal to the Transportation Development Centre (TDC) to develop a program to simulate the operations of a rail line and interface with a dispatch centre.

With this catalytic funding, it was anticipated that further development could be done at the recommendation, and with the financial participation, of a user group of interested supply companies and railways after they have some experience with the simulation package.

TDC, wishing to have the market potential for such a simulator assessed prior to committing to the proposed development, issued a contract to assess interest in the simulation approach and to develop a performance specification for the simulator. This working paper presents the findings of that initial contract.

2. FEATURES OF THE PROPOSED SIMULATOR

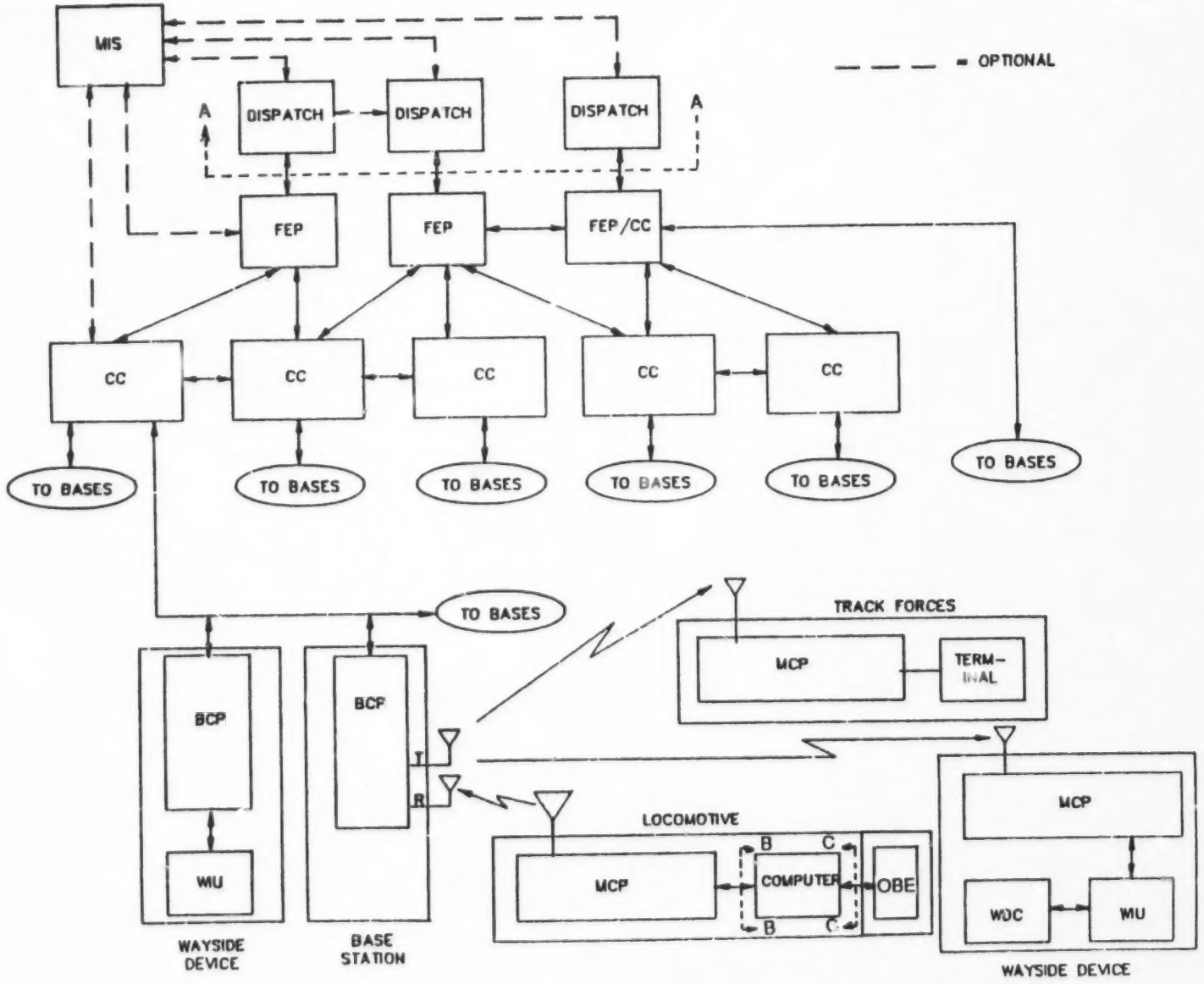
The principal modules of an ATCS system are illustrated in Figure 1. Three of the segments lend themselves to simulation testing: the dispatch centre, the on-board computer, and the communications modules.

The development phases initially proposed were:

(1) an operations simulator which would provide responses representative of those expected for a railway subdivision; its trains, switches and work gangs. This simulator would interface at boundary "A---A" on Figure 1.

(2) a locomotive component simulator which would provide simulated signals at the interface to any component of interest on board the locomotive. The initial focus would be on providing the inputs to the on-board computer. These include such items as tachos, throttle notch setting, air brake setting, and transponder crossings; and would also require a rudimentary version of dispatch authorities from a simulated dispatch centre. The simulator would interface at boundaries "B---B" and "C---C" on Figure 1. Eventually this facility could be developed to permit substitution of any component with real hardware for environmental or functional compliance tests.

(3) a communications simulator which would simulate fading and coverage problems on the land links, and derive its workload from the operations simulator developed in phase 1.



Source: ATCS Spec 2000

Figure 1 ATCS Data System Topology and Major Internal Connections

3. MARKET ASSESSMENT

To assess interest in the proposed simulation facility, invitations were sent to industry, railway and government representatives to attend one of two presentations (one in Montreal and one in Toronto) detailing the proposal. In total 30, people attended or expressed interest in receiving more information on the proposal. A copy of the overheads presented at the meetings is included as Appendix A.

Following the presentations the questionnaire shown in Figure 2 was sent to each of the attendees, soliciting their reaction to the proposal. A total of 14 responses were received. The responses are summarized in Table 1.

Table 1

Simulation Test Facility for ATCS and Like Systems
Questionnaire Results -- Recapitulation

	Question	Suppliers	Regulators	Class I Railways	Class II Railways	Total
III.	Developments have potential value to company?					
	agree	4	1	-	-	5
	disagree	1	-	-	2	3
	undecided	2	2	1	1	6
IV.	Interested in:					
	Level i	1	1	-	-	2
	Level ii	3	1	-	-	4
	Level iii	1	1	-	-	2
V.	Interested in evaluating application?					
	yes	2	1	1	1	5
	no	1	1	-	-	2
VI.	Agree with idea of users' group?					
	yes	5	2	1	2	10
	no	2	-	-	1	3
	Would participate?					
	yes	3	1	1	-	5
	no	3	1	-	3	7
VII.	Would like to have input to performance specifications?					
	yes	6	2	1	-	9
	no	1	-	-	3	4

A Simulation Test Facility for
Advanced Train Control Systems (ATCS)

Questionnaire

I. I represent: a) supplier _____, b) railway_____.
c) regulatory authority _____.
d) other (please specify) _____

II. If (a), my company would be primarily recognized as a:

(a) full systems supplier (___)
(b) communications equipment supplier (___)
(c) ATCS subcomponent supplier (___)

Three levels of development were discussed:

(i) a railway operations simulator that would interface with an ATCS or equivalent dispatch centre. It would provide communications system workloads and permit evaluation of the dispatch centre.

(ii) a full systems test facility that would provide a simulated interface for the locomotive onboard computer or other onboard modules.

(iii) a communications module that, used in combination with the operations simulator, would simulate the delay cycle, fading and dark territory effects on the communications system performance.

III. Any one or all of the three developments are of potential value to my company: agree ___ disagree___ undecided___

IV. If your answer to III was positive, is your priority interest in having a facility for number i ___, ii ___, and/or iii ___.

V. If your answer to III was "undecided", would you be interested in evaluating its application to your needs if the basic simulator were developed. yes ___, no ___.

VI. I agree (___), disagree (___) with the idea of a user's group for subsequent development of the system. If such a group were formed, I would ___, would not ___ consider being a member.

VII. I would like to have an input to the performance specifications of the modules if and when developed. yes ___, no ___.

VIII. Optional Information*

Name: _____
Title: _____
Company: _____
Address: _____
_____
Area Code _____ Telephone _____

* Individual questionnaire responses will be treated in confidence by TDC and CIGGT.

Figure 2(a) Questionnaire

Simulateurs d'opérations ferroviaires pour l'essai des systèmes avancés de contrôle des trains (ATCS)

Questionnaire

I. Je, soussigné, représente : a) la société ____
b) la société ferroviaire ____
c) l'organisme de réglementation ____
d) autre (précisez) _____

II. Si a), mon entreprise est surtout connue comme fournisseur :

a) de systèmes complets (__)
b) de matériels de communication (__)
c) de composants pour ATCS (__)

Les trois options suivantes ont été envisagées :

i) Simulateur d'opérations ferroviaires relié à un ATCS ou un centre de régulation, dont il pourra évaluer les performances en le soumettant à des charges de travail simulées.

ii) Installation d'essai de systèmes complets simulant l'interface avec l'ordinateur à bord de la locomotive ou tout autre module embarqué.

iii) Module de communication qui, parallèlement au simulateur des opérations ferroviaires, pourra simuler l'effet du retard, de l'affaiblissement ou de la disparition du signal sur les performances du système de communication.

III. L'une ou l'ensemble de ces trois options, pourrait intéresser mon entreprise:
Oui __ Non __ Peut-être __

IV. Dans l'affirmative, elle choisirait prioritairement l'option :
i __ ii __ et/ou iii __

V. Si la réponse à III a été peut-être, et si un simulateur de base était effectivement réalisé, mon entreprise pourrait être intéressée à en évaluer son utilité pour ses propres besoins:
Oui __ Non __

VI. Je suis d'accord (__) en désaccord (__) avec l'idée de mettre sur pied un groupe d'utilisateurs visant le développement ultérieur du simulateur. Si un tel groupe était créé, je voudrais __ je ne voudrais pas __ en faire partie.

VII. J'aimerais contribuer à l'élaboration du devis de performances concernant les modules qui seront éventuellement réalisées:
Oui __ Non __

VIII. Informations générales (Facultatif)*

Nom _____
Titre _____
Raison sociale _____
Adresse _____
Indicatif régional ___ Téléphone _____

* Ces informations personnelles resteront confidentielles pour le CDT et CIGGT.

Figure 2(b) Questionnaire

Five organizations felt they would benefit from such a facility and six were undecided. Of the six undecided, five would like to evaluate the first stage simulator for application to their situations.

Most of the interest was in the second stage of development (i.e. the full test facility) but the operations simulator and communications test facility were also of prime interest.

The idea of an ongoing user group was well accepted (ten in favour) but only five indicated they would participate in such a group.

A number of follow-up interviews were held with representatives of the supply industry, railways and the ATCS committee. While there was no consensus of opinion, the following observations were made by the author on the basis of these interviews and discussions at the presentations.

(1) Regulatory authorities have no interest in the facility as a user. They are not actively involved in safety acceptance of railway technology. They do think the facility would be of value to the railways and their supply industries.

(2) The ATCS committee sees its role as one of developing operational and hardware interface specifications. Compliance testing of any proposed equipment is the responsibility of the purchasing railway and its supplier.

(3) Railways agree with the importance and need for simulation. They are not sure who should develop and house such a facility. Some would prefer in-house development. The anticipated problems of liability for a multi-vendor system have been eliminated by the intended use of systems integrating suppliers. These suppliers will have the task of assuring that safety- and operational-related specifications are complied with.

(4) Suppliers see the value of such a facility but as there are few full systems suppliers and no existing market, their interest is primarily in a simulation interface to the on-board computer rather than the operations interface for a dispatch centre.

4. PERFORMANCE SPECIFICATIONS

4.1 The Operations Simulator

Figure 3 illustrates the configuration of the operations simulator and how it would interface with a user's system.

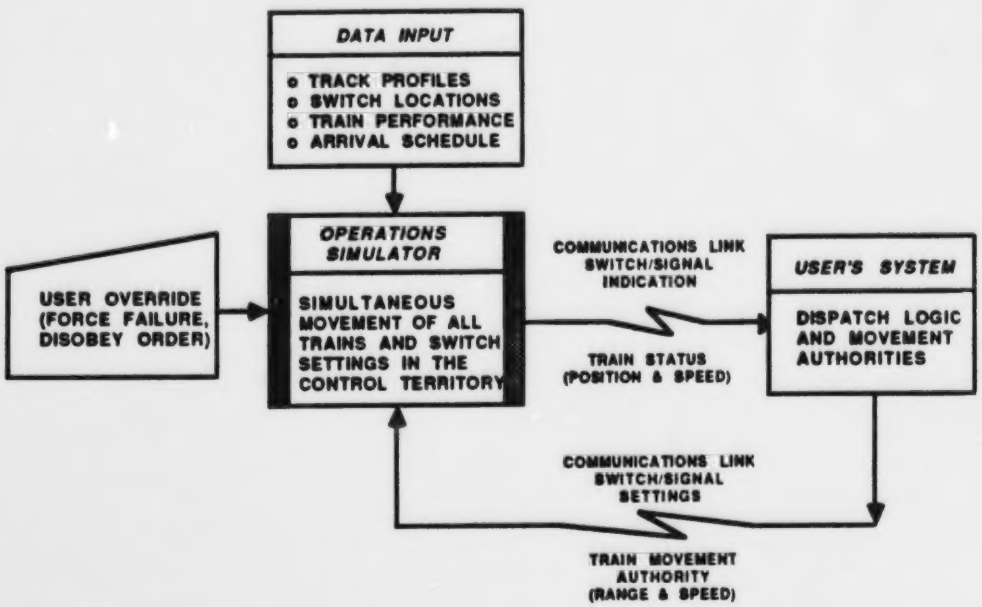

DATA INPUT
o TRACK PROFILES
o SWITCH LOCATIONS
o TRAIN PERFORMANCE
o ARRIVAL SCHEDULE
OPERATIONS SIMULATOR
SIMULTANEOUS MOVEMENT OF ALL TRAINS AND SWITCH SETTINGS IN THE CONTROL TERRITORY
USER OVERRIDE (FORCE FAILURE, DISOBEY ORDER)
COMMUNICATIONS LINK SWITCH/SIGNAL INDICATION
TRAIN STATUS (POSITION & SPEED)
USER'S SYSTEM
DISPATCH LOGIC AND MOVEMENT AUTHORITIES
COMMUNICATIONS LINK SWITCH/SIGNAL SETTINGS
TRAIN MOVEMENT AUTHORITY (RANGE & SPEED)

Figure 3 Configuration of Operations Simulator

The attributes of the operations simulator initially proposed were:

- real time simultaneous simulation of all train, switch and signal actions in a single dispatch territory (initially 200 miles of track);
- can be run on a personal computer (IBM AT) and distributed on diskettes;
- can interface with any advanced train control dispatch centre whose communications protocol is specified;
- trains, switches and wayside signals (if used) would follow the dispatch commands communicated by the host system computer;
- failure of any of the simulated components to obey dispatch commands could be introduced by the operator via manual keyboard entries to the simulation computer;
- can initialize to a given schedule and start time.

From discussions with potential users it was obvious that such a facility would have to be designed to permit the user to readily build his own track configuration rather than accept a predefined test track. A separate interactive preprocessor is envisaged to generate the track layout for use by the main simulator.

The ATCS Data Communications System is structured on the basis of the International Standards Organization's (ISO) model called the *Open System Interconnect (OSI) Reference Model*. This addresses the interconnection and communications of diverse user applications irrespective of their internal designs.

The model provides for a seven-layered division of functions needed to achieve cooperation among applications. These layers are:

LAYER 7: *Application Layer*. Selects appropriate service for the application. (An application is the actual hardware and/or software entity that performs a function in ATCS and requires use of the communications systems. Applications are also sometimes called "users."

LAYER 6: *Presentation Layer*. Provides data formatting (reformatting) and identification.

LAYER 5: *Session Layer*. Coordinates the interaction between applications.

LAYER 4: *Transport Layer*. Provides for ene-to-end data integrity and quality of service in communications.

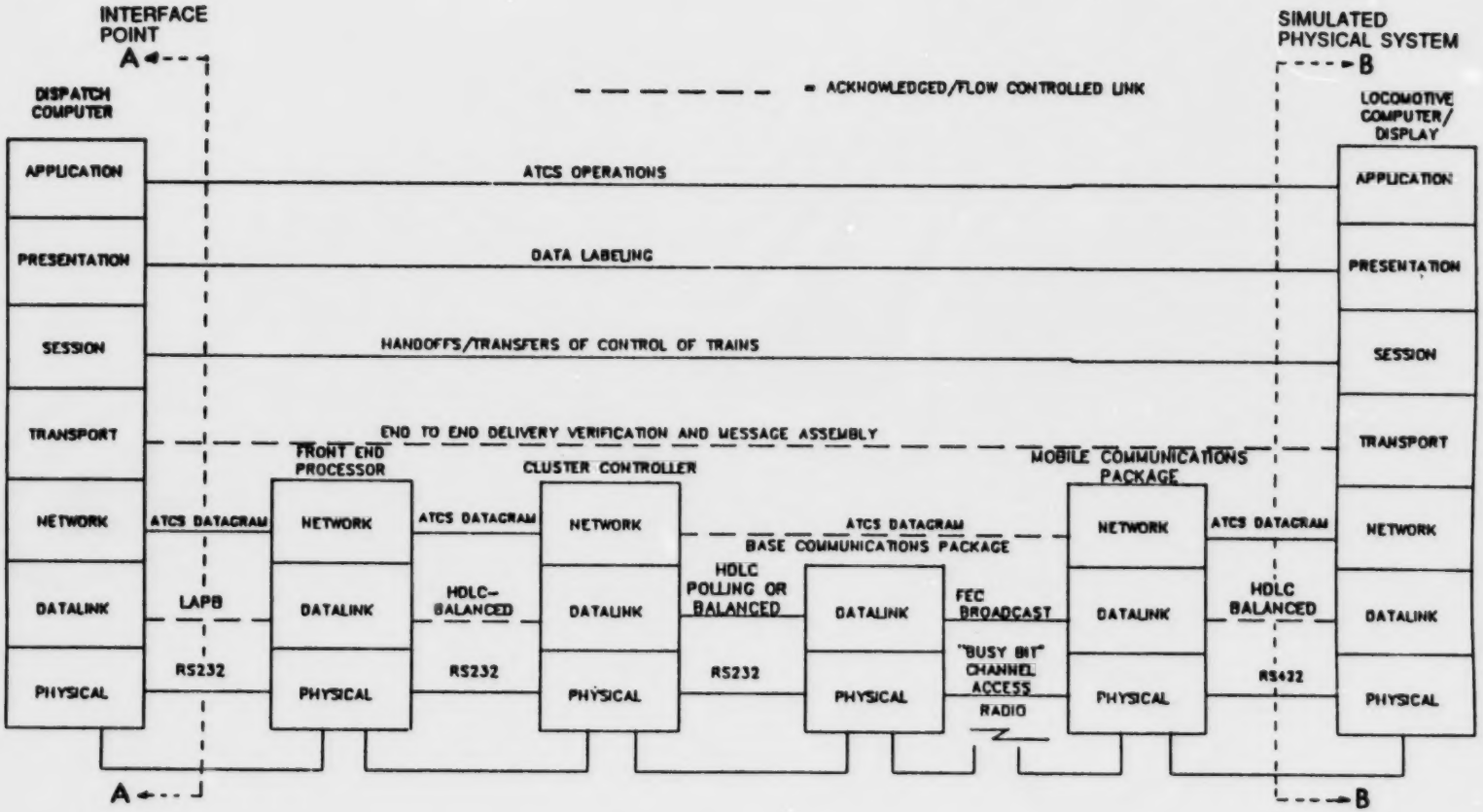
LAYER 3: *Network Layer*. Switches and routes information.

LAYER 2: *Data Link Layer*. Transforms units of information across a physical link. Provides media access control, synchronization, framing, and error detection and recovery.

LAYER 1: *Physical Layer*. Moves bits across a medium.

The seven-layer OSI data communications protocol for the interface of all ATCS communications components is illustrated in Figure 4. The interface point for the simulator was chosen to be after the radio frequency receiver.

The simulator would simulate the physical state of all trains, workforces and remotely operated switches in the dispatch territory (interface boundary "B---B" in Figure 4. The interaction between the simulator and the dispatch centre would be at the boundary "A---A" (i.e. the dispatch computer) shown on Figure 4. The communications interface at the simulation computer would follow the specifications for the dispatch computer interface for OSI layers 1, 2 and 3. With the exceptions noted below, the specifications for the field units at layers 3 to 7 would be followed. The multi-step physical communications system in place for a real application would be ignored in the phase 1 simulator. Thus much of the message routing and access protocol complexities introduced by the radio communications system will be bypassed.



Source: ATCS Spec 200

Figure 4 ATCS Data Network by OSI Layer

The physical link between the two computers will be the RS232 interface specified for the dispatch computer. The data link will follow the ATCS specification for the Link Access Procedure B (LAPB) protocol as defined in CCITT recommendation X.25 Section 2. A 9600-bits-per-second data rate will be assumed.

The simulation computer will route messages originating from the dispatch centre to the appropriate application by following the address format defined in Appendix T of ATCS Specification 200. However, the simulation computer representation will be limited to locomotives, work gangs and switch control units and all field-sourced communications will be limited to accessing the dispatch computer. Thus, locomotive control of switches will not be permitted nor will locomotive-to-locomotive transmissions.

Because the communications interface is a direct port-to-port RS232 connection the simulation computer will not follow the priority queue polling protocol but a first-in/first-out queue. The priority status of the message will, however, be encoded as per ATCS specifications for layer 4 protocols (Appendix D of Specification 200).

Failure modes supported by the simulation computer via its keyboard will include:

- loss of communication with a train (in this case a voice-based communication of new authority, or UCOR action, for that train in terms of speed and mileage authority will be input to the simulation computer keyboard);
- train overspeeding;
- train authority excedence;
- a change in power-to-weight ratio for any train;
- loss of communication with a switch;
- failure of a switch to indicate correct alignment.

4.2 The On-Board Computer Interface Simulator

The simulator for the on-board locomotive equipment was of principal interest to the suppliers. Of the on-board equipment, the on-board computer is the vital component which depends on software development. A simulated interface to this processor was seen as a desirable first step. The requirements of the initial interface is confined to those elements considered to be part of the vital operation of the train. Health monitoring interfaces would not be included at this stage.

The boundaries of the simulated interface to the locomotive on-board computer are illustrated in Figure 5. The protocol for the interface between the Mobile Communications Package (MCP) and the On-board Computer (OBC) has been specified in ATCS document 200. The protocol for interface to the on-board equipment was not available.

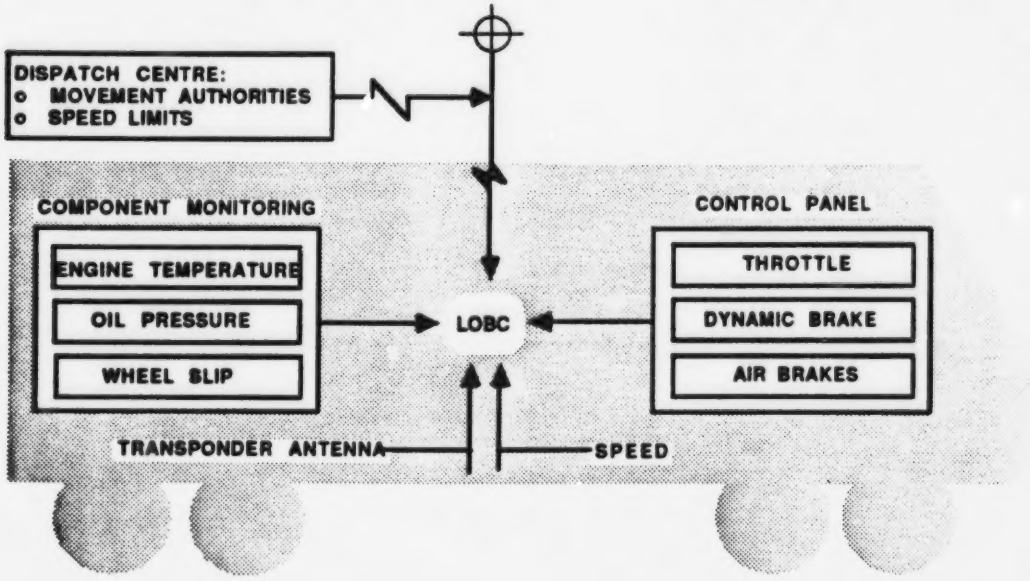


Figure 5 Interface to Locomotive On-Board Computer

The interaction between the simulator and the on-board computer would be at boundary "B---B" (i.e. the locomotive computer) shown on Figure 4. The communications interface at the simulation computer would follow the specifications for the OBC interface for OSI layers 1, 2 and 3. As with the operations simulator, the specifications for the field units at layers 3 to 7 would be followed. The physical link between the two computers will be the RS422 interface specified for the OBC. The data link will follow the High Level Data Link Control (HDLC) balanced protocol as defined in Appendix K of ATCS Specification 200.

As the interface to the on-board equipment is not yet defined, the best means of simulating this interface is not known. It may be transmitted either directly from the simulation computer to the OBC (e.g. data packet from the transponder interrogator) or come from an analogue signal which is controlled by the simulation computer (e.g. brake pipe pressure).

When available, the ATCS 300-series specifications will provide the necessary information to answer these questions.

The functional requirements of this simulator are that it provide a simulated response from the following devices:

- wheel pulse tacho(s);
- transponder crossings;
- throttle setting;
- brake pipe pressure;
- authorities and instructions from the dispatch centre;
- cycling of the air brakes leading to reduced brake pipe pressure.

The main elements of the simulator are illustrated in Figure 6. The control settings of the locomotive will be provided by an expert-system-based driver module which will be sensitive to the control objectives of the particular train being simulated. The train response to the control settings will include probability of wheel slip and initial errors in wheel diameters. The interface with the dispatch centre requires a rudimentary form of dispatch logic. This module will have a capability of giving authorities for train movement in relation to a predefined scenario of stop locations, speed limits, and temporary slow orders.

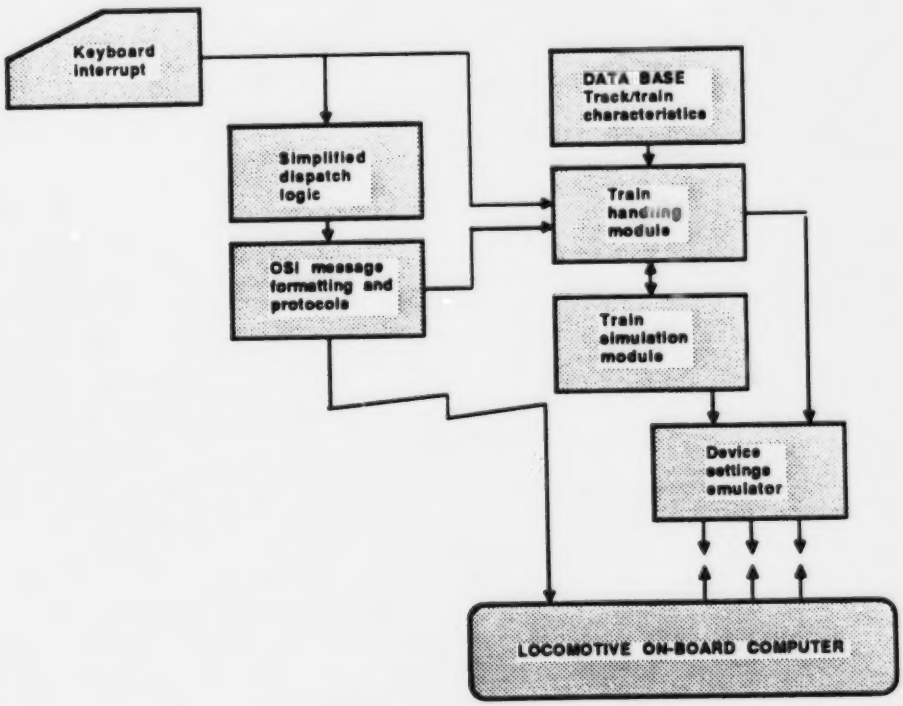


Figure 6 Elements of Simulator

As with the operations simulator, the user may introduce erroneous data via the keyboard of the simulation computer. Following is a list of defined interrupts:

- a defined number of sequentially missed transponders;
- failure of the transponder interrogator;
- failure of the tachometer;
- intermittent failure of the tachometer;
- forced shutdown of one locomotive;
- an error in the defined weight of the train;
- prolonged wheel slip;
- overspeeding of a specified percent for a specified duration;
- excedence of its authority limits;
- loss of data communication with the dispatch centre.

5. CONCLUSIONS

Most of the interest demonstrated by industry was in the development of a full test facility rather than an operations simulator. The first step in this direction which was of immediate interest is a simulated interface to the locomotive on-board computer.

The idea of an ongoing user group was well accepted but only half of those agreeing with the concept indicated that they would participate in such a group. There was general interest in assessing the relevance of an initial development to their particular situation.

The necessary specifications for a simulated interface to a dispatch centre or to an on-board computer are either in place or will be shortly.

On the basis of interviews and discussions, it is recommended that the Transportation Development Centre undertake the initial development of a simulated interface to a locomotive on-board computer rather than an interface to a dispatch centre.

APPENDIX A

PRESENTATION TO INTERESTED INDUSTRY, RAILWAY AND GOVERNMENT REPRESENTATIVES

THE CANADIAN INSTITUTE OF GUIDED GROUND TRANSPORT

DEVELOPMENT

OF A

RAILWAY OPERATIONS

SIMULATOR

AGENDA

- ❑ OBJECTIVES
- ❑ WHAT IS IT?
- ❑ WHY IS IT NEEDED?
- ❑ WHO WILL USE IT?
- ❑ POSSIBLE DEVELOPMENT STEPS
- ❑ YOUR REQUIREMENTS

OBJECTIVES

DEVELOPMENT OBJECTIVE

- TO PROVIDE A RAILWAY OPERATIONS SIMULATOR TO ENABLE OFF-LINE TESTING OF ATCS (OR OTHER) DISPATCH CENTRES

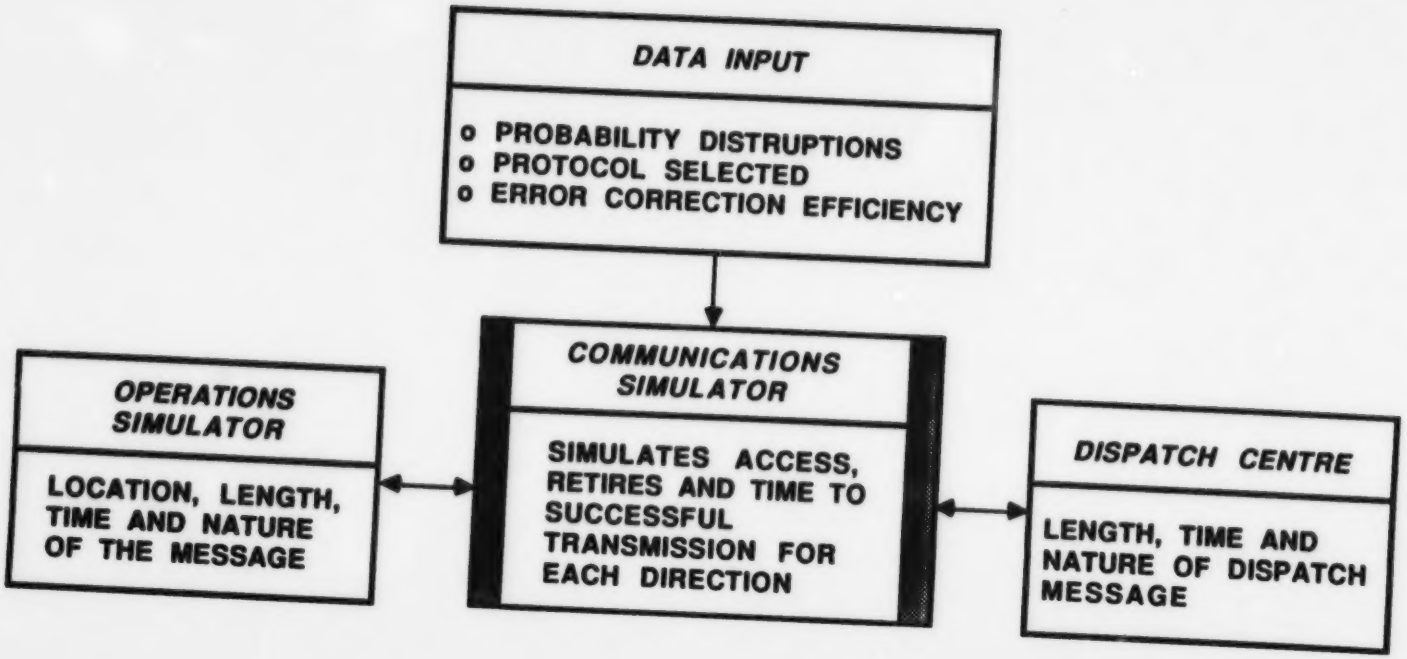
MEETING OBJECTIVE

- TO GET THE FEEDBACK OF POTENTIAL USERS IN ORDER TO ASSESS THEIR NEEDS AND DEVELOP AN ACCURATE PERFORMANCE SPEC

WHAT IS IT?

COMMUNICATIONS SIMULATOR

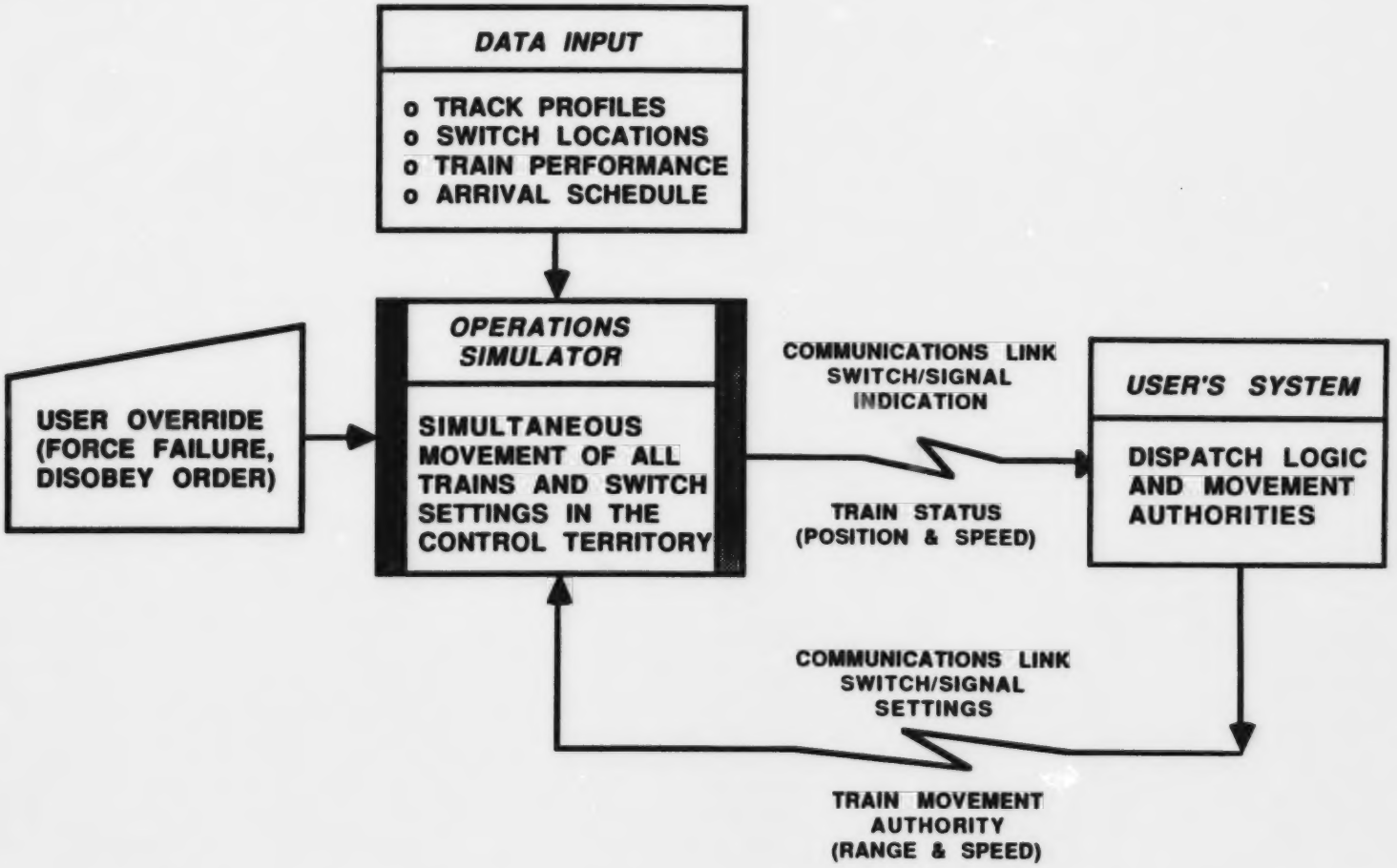
- **INTERFACES TO THE DISPATCH CENTRE AND THE OPERATIONS SIMULATOR**
- **SIMULATES ERROR RATES, LOSS OF COVERAGE, MESSAGE COLLISIONS, RETRIES AND PROPAGATION DELAYS FOR COMMUNICATIONS IN EACH DIRECTION**
- **WILL INCLUDE LOGIC FOR POLLING, ARQ, TDMA AND ATCS RECOMMENDED PROTOCOLS**
- **WILL PERMIT USER SPECIFICATION OF PROBABILITY FUNCTIONS BY TRACK LOCATION**


DATA INPUT
o PROBABILITY DISTRUPTIONS
o PROTOCOL SELECTED
o ERROR CORRECTION EFFICIENCY
OPERATIONS SIMULATOR
LOCATION, LENGTH, TIME AND NATURE OF THE MESSAGE
COMMUNICATIONS SIMULATOR
SIMULATES ACCESS, RETIRES AND TIME TO SUCCESSFUL TRANSMISSION FOR EACH DIRECTION
DISPATCH CENTRE
LENGTH, TIME AND NATURE OF DISPATCH MESSAGE

WHAT IS IT?

OPERATIONS SIMULATOR

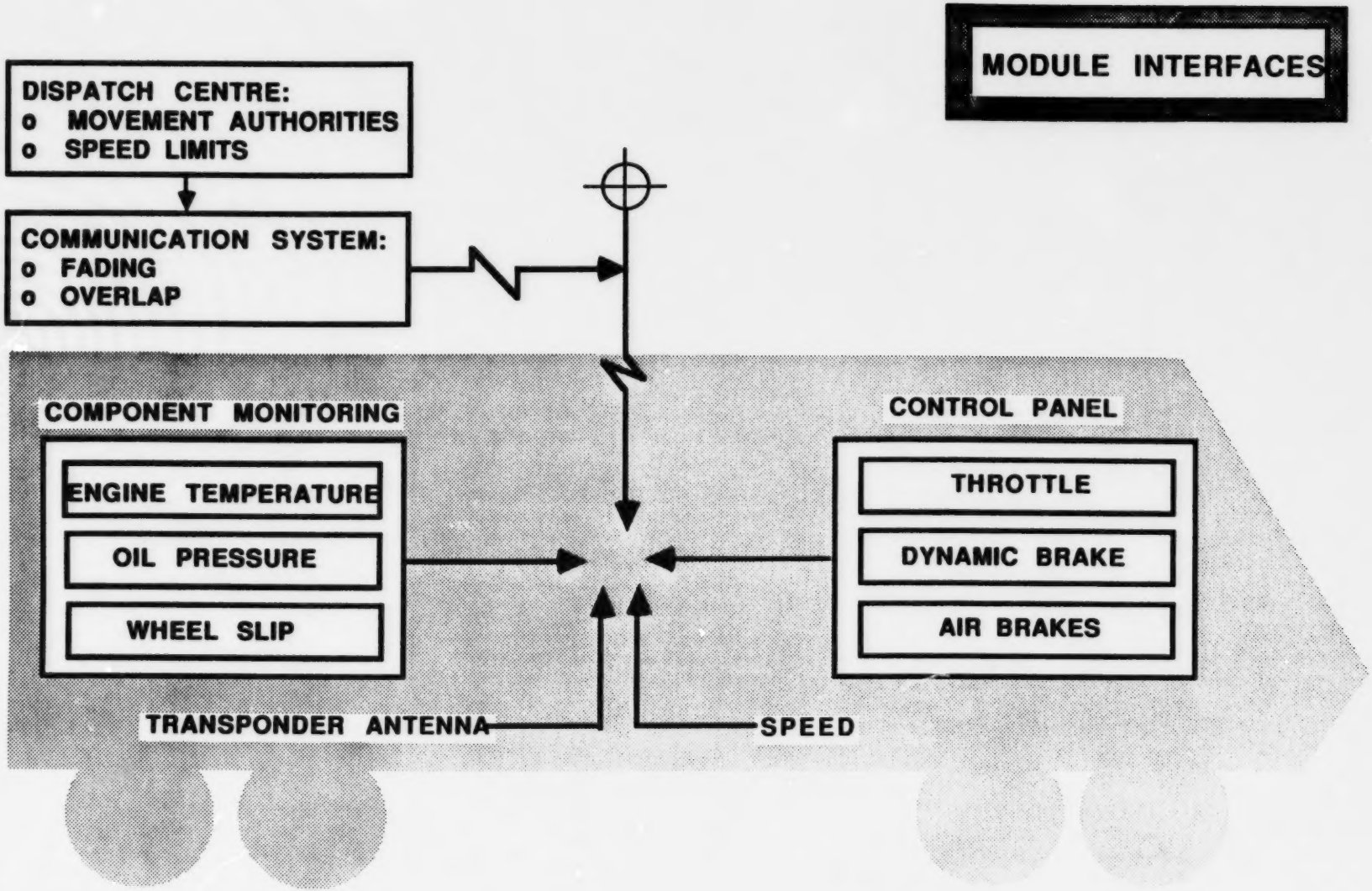
- REAL-TIME SIMULTANEOUS SIMULATION OF ALL TRAIN, SWITCH AND SIGNAL ACTIONS IN A SINGLE DISPATCH TERRITORY (INITIALLY 200 MILES OF TRACK)
- TRAINS, SWITCHES AND WAYSIDE SIGNALS (IF USED) WOULD FOLLOW THE DISPATCH COMMANDS COMMUNICATED BY THE HOST SYSTEM COMPUTER
- WILL INTERFACE WITH ANY ADVANCED TRAIN CONTROL DISPATCH CENTRE WHOSE COMMUNICATIONS PROTOCOL IS SPECIFIED
- FAILURE OF ANY OF THE SIMULATED COMPONENTS TO OBEY DISPATCH COMMANDS COULD BE INTRODUCED BY THE OPERATOR VIA MANUAL KEYBOARD ENTRIES TO THE SIMULATION COMPUTER


DATA INPUT
o TRACK PROFILES
o SWITCH LOCATIONS
o TRAIN PERFORMANCE
o ARRIVAL SCHEDULE
USER OVERRIDE (FORCE FAILURE, DISOBEY ORDER)
OPERATIONS SIMULATOR
SIMULTANEOUS MOVEMENT OF ALL TRAINS AND SWITCH SETTINGS IN THE CONTROL TERRITORY
COMMUNICATIONS LINK SWITCH/SIGNAL INDICATION
TRAIN STATUS (POSITION & SPEED)
USER'S SYSTEM
DISPATCH LOGIC AND MOVEMENT AUTHORITIES
COMMUNICATIONS LINK SWITCH/SIGNAL SETTINGS
TRAIN MOVEMENT AUTHORITY (RANGE & SPEED)

WHAT IS IT?

FULL HARDWARE TEST FACILITY

- A FACILITY WHICH CAN PROVIDE A SIMULATED INTERFACE TO ANY MODULE OR MAJOR COMPONENT TO ASSIST ENVIRONMENTAL OR DEVELOPMENTAL ASSESSMENTS


MODULE INTERFACES
DISPATCH CENTRE:
o MOVEMENT AUTHORITIES
o SPEED LIMITS
COMMUNICATION SYSTEM:
o FADING
o OVERLAP
COMPONENT MONITORING
ENGINE TEMPERATURE
OIL PRESSURE
WHEEL SLIP
CONTROL PANEL
THROTTLE
DYNAMIC BRAKE
AIR BRAKES
TRANSPONDER ANTENNA
SPEED

WHY?

- LOWERS THE COST OF PROTOTYPE DEVELOPMENT
- LOWERS THE RISKS OF ON-SITE FIELD TESTING
- REDUCES THE DURATION OF ON-SITE FIELD TESTING
- ALLOWS MUCH MORE EXTENSIVE TESTING OF OPERATIONAL SITUATIONS
- PROVIDES A COMMON FACILITY TO ALL DEVELOPERS AND USERS

USAGE

WHO WOULD USE IT?

- **RAILWAYS**
- **SUPPLIERS**
- **REGULATORY BODIES**

USAGE

EXAMPLES OF USAGE

- **DEVELOP A BENCHMARK OF COMPARISON:**
  - **o MANUAL DISPATCH SESSION**
  - **o EXPERT SYSTEM INTERFACE**
- **INITIATE COMPONENT FAILURES TO EVALUATE SYSTEM RESPONSE**
- **INITIATE RUNTHROUGHS, OVERSPEEDING OR OTHER RULE INFRACTIONS TO TEST SYSTEM RESPONSE**

METHOD OF USE

ON A USER FEE BASIS TO PROVIDE CUSTOM ENHANCEMENTS OR COMMUNICATIONS PROTOCOL CHANGES

A USERS GROUP MAY BE CONSIDERED FOR LONGER-TERM, MAJOR ENHANCEMENTS

DEVELOPMENT

- ARRIVE AT PERFORMANCES SPECS
- CHOOSE A LANGUAGE
- CODE THE OPERATIONS SIMULATOR:
  - o TRAIN SIMULATION
  - o ROUTING AND FIXED EQUIPMENT SIMULATOR
  - o INITIALIZE ROUTINE
- VALIDATE:
  - o IN HOUSE
  - o RAILWAY AND/OR SUPPLIERS

YOUR REQUIREMENTS

- QUESTIONNAIRE
- SYSTEM SIMULATOR OR COMPONENT INTERFACE
- TRADEOFFS:
  - o SPEED VS. DETAIL
- NON-EQUIPPED TRAINS
- CTC AND WAYSIDE SIGNALS
- BENCHMARK